SHOCK ABSORBING CONCRETE (SACON™)

PART 1 – GENERAL

1.1 SUMMARY

Shock absorbing concrete (SACON) is a material system designed for constructing bullet traps and live fire facilities. The design concept of SACON is its unique air void structure within a portland cement concrete matrix that allows projectiles, 5.56 mm rounds and hand grenade fragments, to penetrate the surface of the SACON and become embedded or trapped just inside the concrete surface. Fiber reinforcements are added tot he mixture to reduce spalling of the SACON and to hold the concrete matrix intact as these projectiles impact and travel into the SACON.

1.2 REFERENCE STANDARDS

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN CONCRETE INSTITUTE (ACI) STANDARDS

ACI 117	(1990) Standard Specifications for Tolerances For Concrete Construction and Materials
ACI 211.2	(1994) Standard Practice for Selecting Proportions for Structural Lightweight Concrete
ACI 304R	(1989) Guide for Measuring, Mixing, Transporting, and Placing Concrete
ACI 301	(1996) Standard Specifications for Structural Concrete
ACI 305R	(1991) Hot Weather Concreting
ACI 306R	(1988) Cold Weather Concreting
ACI 308	(1992; R 1997) Standard Practice for Curing Concrete
ACI 523.1	(1992) Guide for Cast-In-Place Low Density Cellular Concrete
ACI 523.2	(1996) Guide for Precast Cellular Concrete Floor, Roof, and Wall Units
ACI 523.3	(1993) Guide for Cellular Concretes Above 50 PCF and for Aggregate Concrete Above 50 PCF with Compressive Strengths Less Than 2500 PSI

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIAS (AASHTO)

AASHTO M 182	(1991) Burlap Cloth Made from Juto or Konat

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
With Corresponding US Army Corps of Engineers Handbook for Concrete and Cement (CRD) Standards indicated where available.

ASTM A 820	(1996) Steel Fibers for Fiber-Reinforced Concrete (CRD-C 504)
ASTM C 31	(1998) Making and Curing Concrete Test Specimens in the Field (CRD-C 11)
ASTM C 39	(1996) Compressive Strength of Cylindrical Concrete Specimens (CRD C 14)
ASTM C 94	(1999) Ready-Mixed Concrete (CRD-C 31)
ASTM C 109	(1999) Compressive Strength of Hydraulic Cement Mortars (CRD-C 227)
ASTM C 144	(1999) Aggregate for Masonry Mortar
ASTM C 150	(1998a) Portland Cement (CRD C 201)
ASTM C 171	(1997a) Sheet Materials for Curing Concrete (CRD-C 310)
ASTM C 172	(1992) Sampling Freshly Mixed Concrete (CRD-C 4)
ASTM C 309	(1998a) Liquid Membrane-Forming Compounds for Curing Concrete (CRD-C 304)
ASTM C 567	(1999a) Unit Weight of Structural Lightweight Concrete (CRD-C 75)
ASTM C 796	(1987a; 1997) Foaming Agents for Use in Producing Cellular Concrete Using Pre-Formed Foam (CRD-C 518)
ASTM C 869	(1991) Standard Specification for Foaming Agents Used in Making Pre-Formed Foam for Cellular Concrete (CRD C 81)
ASTM C 1116	91995) Standard Specification for Fiber-reinforced Concrete and Shotcrete (CRD-C 627)

US ARMY CORPS OF ENGINEERS HANDBOOK FOR CONCRETE AND CEMENT (CRD)

CRD-C 400	(1963) Requirements for Water for Use in Mixing or Curing Concrete

NATIONAL READY-MIXED CONCRETE ASSOCIATION (NRMCA)

NRMCA QC 3	(Jan 1984) Quality Control Manual: Section 3, Plant Certifications Checklist: Certification of Ready-Mixed Concrete Production Facilities
NRMCA CPMB 100	(Jan 996) Concrete Plant Standards
NRMCA TMMB 1	(1994) Truck Mixer and Agitator Standards

1.3 SUBMITTALS

Submit the following in accordance with Section 01330. “Submittal Procedures”

SD 01 Preconstruction Submittals

Qualifications of the testing agency conducting and evaluating aggregate testing and the SACON mixture.

SD 03 Product Data

Stabilizing Agent; G

Foaming Agent; G

Fiber Reinforcement; G

SD 01 Samples

SACON Test Panels; G

SD 05 Design Data

Proportions of Mixture; G

The results of trial mixtures along with a statement giving the proportions of all ingredients that will be used in the manufacture of SACON shall be provided, prior to commencing concrete placing operations. Aggregate weights shall be based on the saturated surface dry condition. No substitutions shall be made in he materials used in the manufacturing of SACON.

Forms: G

The contractor shall provide a sketch or drawing indicating the formwork, dimensions and shapes.

SD 06 Test Reports

Aggregate

Admixtures

Curing Compound

The contractor shall provide certified copies of laboratory test reports, including all Test data. These tests shall be made by an approved commercial laboratory or by a Laboratory maintained by the manufacturers of the material.

SD 07 Certificates

Cementitious Materials

The contractor shall maintain manufacturer's certification of compliance for portland Cement, accompanied by mill test reports attesting that the materials meet the requirements of the specification under which it is furnished. No cement shall be used until Notice of acceptance has been given. The cement may be subjected to check testing by the Government from samples obtained at the mill, at transfer points, or at the project site.

1.4 GENERAL REQUIREMENTS

Tolerances for concrete construction and materials shall be in accordance with ACT 117.

1.4.1 Shock Absorbing Concrete (SACON)

SACON is comprised of a cement slurry, an air void system of pr-formed foam, and fiber reinforcement.

1.4.1.1 Strength Requirements

SACON for all work shall have a minimum 28 day unconfined compressive strength of 4.48 Mpa and a maximum 28 day unconfined compressive strength of 10.3 Mpa as determined in accordance with ASTM C 109.

1.4.1.2 Density

SACON shall have a pre-fiber density of 1442 ± 32 kg/m^3 and a post fiber density of 1458 ± 32 kg/m^3 with polypropylene fibers as determined in accordance with ASTM C 567.

1.4.1.3 Slurry

SACON slurry shall be pre-mixed in the mixer. The slurry mixture shall consist of portland cement, fine aggregate, water, and a foam stabilizer.

The slurry shall have a density of 2099 ± 32 kg/m^3. The check of slurry density provides a quality control tool for the mixing action of the mixer and the introduction of fiber materials into the mixer.

1.4.1.4 Slump

SACON shall not be tested for a slump value.

1.5 MIXTURE PROPORTION

Trial batches shall contain materials proposed to be used in the project. Trial mixtures having densities, proportions, and consistencies suitable for the work shall be made. Trial mixtures shall be proportioned to produce the SACON properties specified up to and including the location point of conveyance into the formwork. The density of the SACON shall be the primary property that controls the mixture proportioning. The density of freshly-mixed SACON without fibers shall be 1442 ± 32 kg/m^3 as determined in accordance with ASTM C 567.

The mixture proportion of SACON without color pigments shall be as follows:

	Per Cubic Meter
Cement:	577 kg
Fine Aggregate	577 kg
Foam Stabilizer	0.15 kg
Void (Foam)	0.33 m^3 (approximate
Fiber (choice of)	
Steel	115 kg
Polypropylene	8.8 kg
REQUIRED DENSITY	
(without fibers)	1442 kg/m^3

A slump extender or high range water reducer may be added.

1.6 STORAGE OF MATERIALS

1.6.1 Cement

Cement shall be stored in weather light buildings, bins, or silos which will exclude moisture and contaminants.

1.6.2 Aggregates

Aggregate stockpiles shall be arranged and used in a manner to avoid excessive segregation and to prevent contamination with other materials or with other sizes of aggregates.

1.6.3 Admixtures and Agents

Admixtures, agents, and other materials shall be stored in such a manner as to avoid contamination and deterioration. Admixtures shall be stored to prevent freezing.

PART 2 – PRODUCTS

2.1 CEMENTITIOUS MATERIAL

Cementitious material shall each be of one type and from one source when used in concrete which will have surfaces exposed in the finished structure. The cement shall conform to ASTM C 50, Type I or II. Pozzalonic additives are not normally used in the manufacture of SACON due to the length of curing required.

2.2 AGGREGATES

Aggregates shall conform to ASTM C 44. SACON shall not contain aggregate particles greater than 2.36 mm. Minimum grading requirements for the fine aggregate shall be those specified in ASTM C 144.

2.3 FIBER REINFORCEMENT

2.3.1 Polypropylene Fiber

Fiber shall be fully oriented, 100% virgin polypropylene, collated fibrillated fiber, 20 mm. long, and shall comply with ASTM C 1116, 4.1.3.

2.4 ADMIXTURES

2.4.1 Foaming Agent

Foaming agent shall comply with ASTM C 869, tested in accordance with ASTM C 796.

2.4.2 Foam Stabilizing Agent

Hydroxypropyl methylcellulose powder limits shall be 19.0 to 24.0% methoxyl and 7.0 to 12.0% hydroxypropoxyl, similar to Dow Chemical Co. K100M.

2.5 WATER

Water shall be potable, except that non0potable water may be used if it complies with the requirements of CRD-C 400. Water for curing shall not contain any substance injurious to concrete, or which causes staining.

2.6 FORMS

Wall panels shall be constructed with pre-cast units of specified shapes and dimensions. Alternative shapes and dimensions shall be allowable pending prior Government approval.

2.6.1 Form Release Coatings

Form release coatings may be used to serve as a bond breaker between the form surface and the SACON.

2.6.1.1 Silicone Coating

A silicone coating, if used, shall be sprayed onto the forms surfaces that are to be in contact with the SACON. No petroleum products of any kind other than the silicone shall be used. Petroleum products have shown a great tendency to collapse the pre-formed foam in SACON.

2.6.1.2 Polyethylene Sheeting

Polyethylene sheeting, if used, shall cover the individual form pieces. The form pieces shall be individually wrapped ad stapled or bonded with an epoxy or glue adhesive prior to assembly. Sheeting shall be a minimum of 6 mils in thickness.

2.7 EMBEDDED ITEMS

Embedded items shall be as indicated, and shall be secured firmly in forms to prevent movement during SACON placement.

2.8 CURING MATERIALS

2.8.1 Burlap

AASHTO M 82.

2.8.2 Impervious Sheets

ASTM C 71, type optional, except that polyethylene film, if used, shall be white opaque.

2.8.3 Membrane Forming Curing Compound

ASTM C 309, Type 1-D, Class A or B.

PART 3 – EXECUTION

3.1 PREPARATION OF SURFACES

Surfaces to receive SACON shall be clean and free from frost, ice, mud, water, and other contaminants.

3.2 BATCHING, MIXING AND TRANSPORTING SACON

SACON mixed in ready-mixed concrete trucks shall be batched, mixed and transported in accordance with ASTM C 94, except as otherwise specified. Truck mixers, agitators, and non-agitating units shall comply with NRMCA TMMB 1. Ready mix plant equipment and facilities shall be certified in accordance with NRMCA QC 3. Site-mixed concrete shall be mixed in accordance with ACI 301. On-site plant shall conform to the NRMCA CPMB 100.

3.2.1 Cement Slurry

The cement slurry, comprised of cement, fine aggregate, water, foam stabilizer, and concrete color pigment, shall initially be batched in a stationary mixer or transit (ready-mix) truck and delivered to the casing site for addition of the other ingredients. The mixer configuration shall be such as to allow adequate mixing with a minimum of cement balling and lumping. The stabilizer shall be pre-blended with a minimum of an equal amount of cement volume prior to addition into the mixer.

3.2.2 Air Void Structure

The void material, a pre-formed foam, shall be added to the cement slurry to obtain the required density. The material shall be added in increments to reduce the possibility of exceeding the SACON density tolerances. The recommended procedure is to add the foam in half increments, i.e. add half of the foam initially by time of insertion and calculate the density; if density remains above the upper tolerance, add half of the remaining foam and re-calculate the density; if density remains above the upper tolerance, then add half of remaining foam until the density tolerance of $\pm$ 32 kg/m^3 has been achieved.

3.2.2.1 Pre-Formed Foam

The foam shall be pre-formed through a foam generator. A concentrated foaming agent shall be mixed with potable water into an aqueous solution in accordance with manufacturer specifications. The solution is pulled into the generator by a vacuum and is expanded into a foam as it passes through a cylinder of glass beads that introduces air into the solution. The foam generator transforms the solution into foam at an expansion rate of 30 to 1. The foam shall be added to the slurry in increments. The foam output from the foam generator shall be verified prior to each day's batching. The output time shall be calculated by determining the time required to fill a known volume container with a minimum volume capacity of 0.56-m^3 (15-gal). A flow rate in cubic meters per second shall be calculated.

3.2.3 Fiber Reinforcement

The fibers shall be the final ingredients added to the SACON mixture following the final density determination. Fibers shall be introduced into the mixture in such a fashion as to minimize clumping or balling.

3.2.3.1 Polypropylene Fibers

Polypropylene fibers shall be added by hand into the mixer. Water soluble bags shall not be tossed into the mixer. The fibers shall add less than 16 kg/m^3 to the final density.

3.2.4 Control of Mixing Water

No water from the truck system or elsewhere shall be added to the cement slurry or the SACON mixture after the initial introduction of mixing water for the batch.

3.3 SAMPLING AND TESTING

Sampling and testing shall be the responsibility of the Contractor, unless stated otherwise, and shall be performed by an approved testing agency.

3.3.1 Aggregate

Aggregates for SACON shall be sampled and tested in accordance with ASTM C 144. Gradation tests shall be performed twice on the first day and every other day thereafter during concrete construction.

3.3.2 SACON Mixture Sampling

Initial sampling of SACON to control the density shall be performed on the initial portion of each batch. Additional sampling shall be performed as often as needed to obtain the specified density. SACON samples shall not be rodded or vibrated; the sides of the molds shall be lightly tapped to obtain a smooth surface.

3.3.2.1 Density of SACON Mixture

Tests for density of SACON shall be performed on the initial portion of each batch. Tests shall be conducted as often thereafter as needed to control the density. The 0.0135 cubic meter cylindrical sample molds (ASTM C 567) or a 0.00283 m^3 (0.1 ft^3) standard bucket filled with SACON shall be weighed for density measurement and then returned to the mixer. Following the final density determination, the batch shall be sampled twice for continuity. The density of freshly mixed SACON shall not vary more than ± 32 kg/m^3 from the corresponding density of the approved proportions. The fiber reinforcement shall be added after the final density determination. Additional samples of SACON for hardened SACON density and unconfined compressive strength tests shall be taken in accordance with ASTM C 172. All test cylinder samples shall be taken at the point of concrete delivery into the formwork.

3.3.3 Evaluation and Acceptance of SACON Mixture

The initial evaluation and acceptance of SACON shall be by the density determination. If the density of any batch of SCON is less than the required density, that batch shall be immediately discarded without any attempts to increase the density. Densities higher than the required limit may be reduced to acceptable limits by foam addition.

3.3.3.1 Frequency of Testing

Each batch of SACON shall be sampled and tested for density and unconfined compressive strength.

3.3.3.2 Testing Procedures

Cylindrical specimens of SACON for testing shall be molded in accordance with ASTM C 31 except the rodding procedure shall no be performed. The specimens shall be cured identically to the cast SACON panels. They shall be stored at the casting site and protected from disturbance. Cylinders shall be tested for density and unconfined compressive strength determination in accordance with ASTM C 39.

3.3.4 Evaluation and Acceptance of SACON Panels

SACON panels will be penetration tested to verify the structural stability of the cast panels and to determine the date on which the panels can be placed into service. Testing and evaluation of the panels will be completed within 30 calendar days after the test panels have arrived at the testing site.

3.3.4.1 SACON Test Panels

The contractor shall provide 2 full size test panels of each panel configuration required by this project. The panels shall represent at least two different batches of SACON mixture. The panels shall be cured for 28 days in their fabrication location then transported to the project site. At the project site, the Government will perform and evaluate a penetration test on each panel as described below. Those panels failing to meet the penetration depth requirement shall be discarded without further testing or modifications. Panels that do meet the penetration shall be utilized in the construction.

3.3.4.2 Penetration Testing

All cast test panels will be individually tested with a live fire test of an M855 round fired from an M16A2 rifle at a distance of 25 meters and the panel shall be measured for penetration depth measured to the back of the bullet. Any penetration depth greater than 125-mm or less than 25-mm will constitute a failure.

3.4 CONVEYING

3.4.1 Requirements

SACON shall be conveyed from mixer to forms as rapidly as possible and within 60 minutes after the fibers have been added by methods which will prevent sergregation, loss of ingredients, or changes in density.

3.4.2 Chutes

When SACON can be place directly from a transit mixer or other transporting equipment, chutes attached to this equipment may be used.

3.4.3 Buckets

Bucket design shall be such that SACON can be discharged without loss of materials. Bucket gates shall be essentially grout tight when closed. The bucket shall provide means for positive regulations of the amount and rate of deposit of concrete in each dumping position. The bucket shall be of such design as to allow no more than a 600 mm drop into the forms.

3.4.4 Belt Conveyors

Belt conveyors shall be designed for conveying grouts and shall be operated to assure a uniform flow of SACON to the final place of deposit without segregation or loss of material. Conveyors

shall be provided with positive means for preventing segregation of the SACON at transfer points and point of placement.

3.4.5 Pumps

Pumping SACON, if approved, shall be conveyed by positive displacement pumps. Pumps shall be the piston or squeeze pressure type. Pipelines shall be steel pipe or heavy duty flexible hose. If a reducer is required from the pump to the hose, then a cone reducer with a one-inch reduction for each twelve inches of reducer shall be used. The pump and hose size shall be matched to eliminate unnecessary back pressures and flow constraints. Distance to be pumped shall not exceed the limits recommended by the pump manufacturer. SACON shall be supplied to the pump continuously. When pumping is completed, the SACON remaining in the pipeline shall be ejected without contaminating the SACON already in place. After each use, the equipment shall be thoroughly cleaned. Flushing water shall be washed outside the forms.

3.5 SETTING MISCELLANEOUS MATERIAL

Place and secure anchors and bolts, pipe sleeves, conduits, and other such items in position before concrete placement. Temporarily fill voids in sleeves with readily removable material to prevent the entry of concrete.

3.6 PLACEMENT

SACON which is transported in transit mixers or agitators or SACON which is truck mixed, shall be discharged within 1 hour or before the drum has revolved 300 revolutions, whichever comes first after the introduction of the fibers to the mixture. When the SACON temperature exceeds 30 degrees C, the time shall be reduced to 45 minutes. SACON shall be place in the forms within 15 minutes after it has been discharged from the truck.

3.6.1 Placing Operation

SACON shall be handled from the mixer to forms in a continuous manner until the approved batch of SACON has been placed. Adequate scaffolding, ramps, and walkways shall be provided so that personnel and equipment are not supported by in-place reinforcement. Placing shall not be permitted when the sun, heat, wind, or limitations of facilities furnished by the Contractor prevent proper consolidation, finishing, and curing. SACON shall be deposited as close as possible to its final position in the forms, and there shall be no vertical drop greater than 600-mm except where suitable equipment is provided to prevent segregation and where specifically authorized. Depositing of the SACON shall be so regulated that it will be effectively consolidated in horizontal layers not more than 600-mm thick, except that all slabs shall be placed in a single layer. Fiber dispersion in the mixture shall b monitored continuously at the point of discharge into the forms. Should fiber clumping or balling be observed, the concrete placement operation shall be temporarily suspended until the fibers are thoroughly dispersed in the mixture.

3.6.2 Consolidation

SACON shall be consolidated by means of a screed vibrated very slightly to smooth the surface or light tapping of formwork with a mallet. Excessive vibration of SACON may result in the collapse of the pre-formed foam, and shall not be allowed.

3.6.3 Cold Weather Requirements

Cold weather concreting shall be performed in accordance with ACI 306R except as specified herein. Special protective measures shall be taken to protect freshly-mixed SACON if freezing temperatures are anticipated before the expiration of a specified 14 day initial curing period. The ambient temperature of the air where SACON is to be placed and the temperature of surfaces to

receive SACON shall be not less than 4.5 degrees C. The temperature of SACON when placed shall be not less than 10 degrees C nor more than 24 degrees C. Heating of the mixing water shall be required to regulate the SACON placing temperature. Materials entering the mixer shall be free from ice, snow, or frozen lumps. Salt, chemicals or other material admixtures shall not be incorporated in SACON in an attempt to prevent freezing.

3.6.3.1 Special Protective Measures

In the event that freezing temperatures are likely to occur during the initial 14-day curing period, the forms shall be placed in an area protected from the freezing temperatures. The area shall be protected by means of heaters and may include storage buildings, tents, warehouse, etc. The initial curing period of SACON shall not be less than 4 days. The forms shall not be stacked to gain space nor moved to a protected area after placement and prior to the full initial curing period.

3.6.4 Hot Weather Requirements

Hot weather concreting shall be performed in accordance with ACI 305R except as specified herein. The placing of SACON during the daylight hours of warm weather shall be limited by the maximum atmospheric temperature and wind velocity. The temperature of SACON placed during warm weather shall not exceed 30 degrees C. The mixing water and fine aggregates shall be cooled, if necessary, to maintain a satisfactory placing temperature. In no case shall the placing temperature exceed 35 degrees C. Wind velocities shall be limited to prevent blowing dust from contaminating the materials, the SACON, or the forms.

3.7 FINISHING

3.7.1 Formed Surfaces

The formed surfaces of SACON shall be as smooth and flat as the formwork except where large protrusions may occur that shall be sanded or ground to an even finish.

3.7.2 Unformed Surfaces

The unformed surfaces of SACON shall not be finished other than screeding to a level surface. Any additional finishing to the surface may cause the surface of the SACON to be excessively hard.

3.8 CURING AND PROTECTION

3.8.1 General

SACON shall be initially cured for a period not less than 14 days with no movement, de-forming, or freezing temperatures. Sides of forms that will be reused may be removed after 3 days. Immediately after placement, SACON shall be protected from premature drying extremes in hot temperatures and high winds, rapid temperature changes, mechanical injury, and injury from rain and flowing water. Air and forms in contact with SACON shall be maintained at a temperature above freezing for the first day and at temperatures above 0 degrees C for the remainder of a specified 4 days curing period. Exhaust fumes from combustion heating units shall be vented to the outside of the enclosure and heaters and ducts shall be placed and directed so as not to cause areas of overheating and drying of concrete surfaces or to create fire hazards. All materials and equipment needed for adequate curing and protection shall be available and at the site prior to placing SACON. No fire or excessive heat shall be permitted near or in direct contact with SACON at any time. Curing shall be accomplished by any of the following methods, or combination thereof, as approved.

3.8.2 Moist Curing

SACON to be moist-cured shall be maintained continuously wet for the entire 14 day curing period. When wooden forms are left in place during curing, they shall be kept wet at all times. If the forms are removed before the end of the curing period, curing shall be carried out as on unformed surfaces, using suitable materials. Horizontal surfaces shall be cured by ponding, by covering with a 50-mm minimum thickness of continuously saturated sand, or by covering with waterproof paper, polyethylene sheet, polyethylene-coated burlap or saturated burlap.

3.8.3 Membrane Curing

The curing compound selected shall be compatible with any subsequent paint, roofing, waterproofing or flooring specified. Membrane curing compound shall not be sued on surfaces that are maintained at curing temperatures with free steam. Curing compound shall be applied to formed surfaces immediately after the forms are removed and prior to any patching or other surface treatment except the cleaning of loose sand, motar, and debris from the surface. Surfaces shall be thoroughly moistened with water and the curing compound shall be applied to slab surfaces as soon as the bleeding water has disappeared, with the tops of joints being temporarily sealed to prevent entry of the compound and to prevent moisture loss during the curing period. Compound shall be applied in a one-coat continuous operation by mechanical spraying equipment, at a uniform coverage in accordance with the manufacturer's printed instructions. SACON surfaces which have been subjected to rainfall within 3 hours after curing compound has been applied shall be re-sprayed by the method and at the coverage specified. Surfaces coated with curing compound shall be kept free of foot and vehicular traffic, and from other sources of abrasion and contamination during the during period.

3.9 ERECTION

The SACON panels shall be constructed and erected as pre-cast units. The units shall be supported during tilting operations to avoid cracking.

---End of Section---